# Characterization of Surficial Sediments From an Island of Wax Lake Delta, Louisiana (USA)

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## Abstract

Delta wetlands are an important depositional environment where rivers meet the coast. These wetlands form natural barriers to erosion and may influence the quality of river water that discharges to the ocean. This study characterizes the composition of delta wetland sediment through analysis of grab samples from Mike Island within Wax Lake Delta, Louisiana (USA). The sediment characterization is part of a broader study that assessed spatial variations in nutrient removal on the island. We collected sediment cores to an approximate depth of 20-30 cm at five sites that spanned levee and lagoon environments. Multiple grain size and organic matter characteristics were measured on the sediment samples, including loss on ignition, as a proxy for organic content, and mud fraction using hydrometer analysis. The samples have a range of mud fractions from approximately 40 to 90%. Samples from the levee are more sand-rich and have a range of organic matter contents from 0.85 to 10.81%. These results support our understanding of the relationships among delta morphology, surficial sediment characteristics, and nutrient removal rates in delta wetlands.

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## Introduction

Deltas are regions of rapid deposition that form where rivers meet the ocean. They control the accretion and erosion of nearby coastal environments and play a critical role in the growth of new coastal wetlands. The morphology of deltas can vary widely depending on their age, exposure to waves and currents, and numerous other factors. Deltas with multiple active channels distribute sediment to nearby beaches and coastal environments, whereas, deltas with one primary channel starve these environments of sediment while accumulating sediment at the distal margins of the delta (Oertel 1977). The growth of a delta is cyclic and marked by constructional and destructional phases (Scruton 1960).

As a delta grows, wetlands and channel networks form on the delta top. These estuary environments provide a large number of ecosystem services. As an example, the Louisiana coastline, which is heavily influenced by river deltas, is a major fishery. Deltas provide the habitat and nutrients needed to sustain a large population of aquatic macrofauna (Chesney et al. 2000). Also, deltas are important for ecotourism. The Danube Delta serves as an example, where more than 88,000 people visit the area each year to see the over 500 species living there (Tâtar et al 2017). This tourism is crucial for the economic vitality of coastal communities. Deltas also influence water quality. They are the last environment through which nutrients pass on their way from watersheds to the ocean. Deltaic wetlands remove nutrients through natural processes, including assimilation and denitrification (Knights et al. submitted). Nutrients can also be recycled through the mineralization of nitrogen and phosphorous in organic matter that is deposited in deltas (Twilley 2009).

This study aims to characterize sediments in a delta island within Wax Lake, Louisiana and is part of larger study on nutrient removal within the delta (Knights et al. submitted). Wax Lake Delta has been the focus of a large number of studies on the morphodynamics, ecology and biogeochemistry of modern deltas. Rosen and Xu (2013) explored the growth of islands in the delta. Carle et al. (2014) characterized vegetation density and plant communities across the delta. Knights et al. (submitted) examined nutrient cycling across one island and used models to upscale nitrate removal rates across the entire delta. This study contributes to the large body of research on Wax Lake Delta by providing new information on the grain size and organic matter content of shallow sediment samples. I show that the levee regions are relatively more sand-rich and exhibit a wide range of organic matter contents. Across all sites, the mud fraction ranged from approximately 30-70%, the sand fraction was 30-70%, and the organic matter content was 0.45-10.81%.

## GEOLOGIC SETTING

Wax Lake Delta is a river-dominated delta in Atchafalaya Bay (Louisiana, USA) that has multiple arrowhead-shaped islands divided by river channels (Figure 1). Delta growth initiated in the 1940's when part of the Mississippi River was redirected by the Army Corps of Engineers (Rosen and Xu 2013). The delta top emerged in the early 1970's after record flooding (Rosen and, Xu 2013). Presently, the delta surface ranges in elevation from -1 to roughly 3 m, referenced to the NAVD88 datum (Olliver and Edmonds 2017). The elevations of the study sites on Mike Island range from -0.14 to 0.25 m. Mean sea level on Wax Lake Delta is 0.116 m with a tidal range of 0.35 m. The daily discharge from Wax Lake Outlet at Calumet, LA (USGS Gage 07381590) is ~2500 $m^3$ $s^{-1}$. Salinity of the delta is relatively low (<0.5 ppt).

Wax Lake Delta can be divided into ecogeomorphic zones based on land elevation and vegetation. Relatively high, subaerial regions such as island apexes tend to have dense emergent vegetation evident as relatively large NDVI values (Figure 1b). These regions host colonies of *Salix Negra* (Black Willow). Marginally lower levees are inhabited by *Colocasia esculenta* (Elephant Ear) intermixed with herbaceous vegetation, such as *Polygonum punctatum* (Dotted Smartweed). Even lower elevations in the center and distal portions of islands are continuously submerged and have either no emergent vegetation or contain floating vegetation such as *Nulembo Lutea* (American Lotus) (Carle et. al 2014). These regions have the lowest NDVI values (Figure 1b).

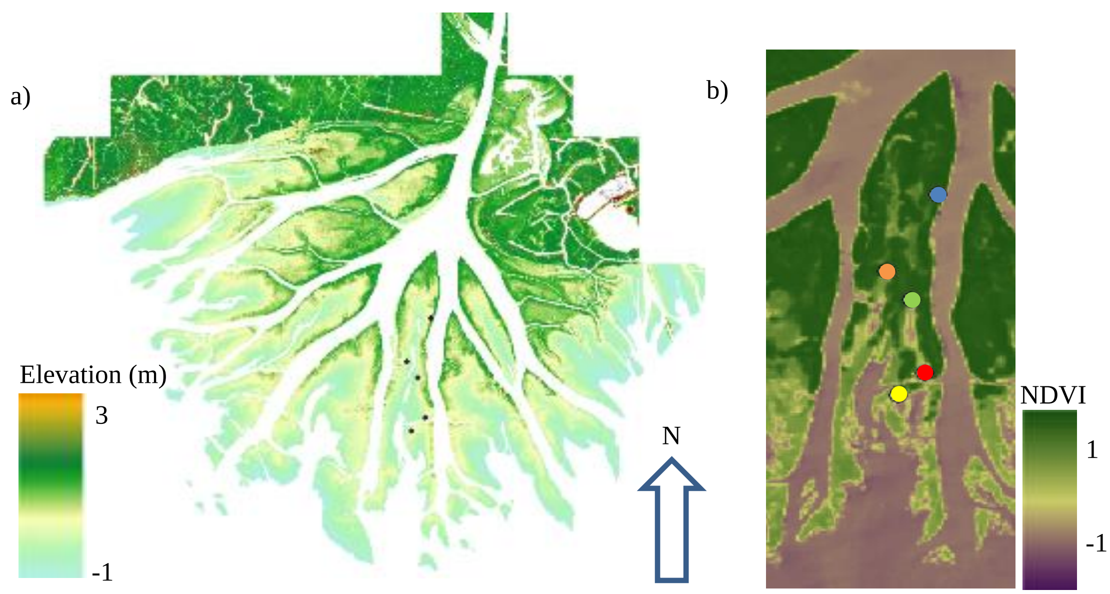


**Figure 1**. a) Digital Elevation Model (DEM) of Wax Lake Delta, with sites. b) Zoomed view of Mike Island showing NDVI, a measure of greenness. Field sites are shown with circles. Colors correspond with color scheme in Figure 3.

## Methods

### Sediment Collection

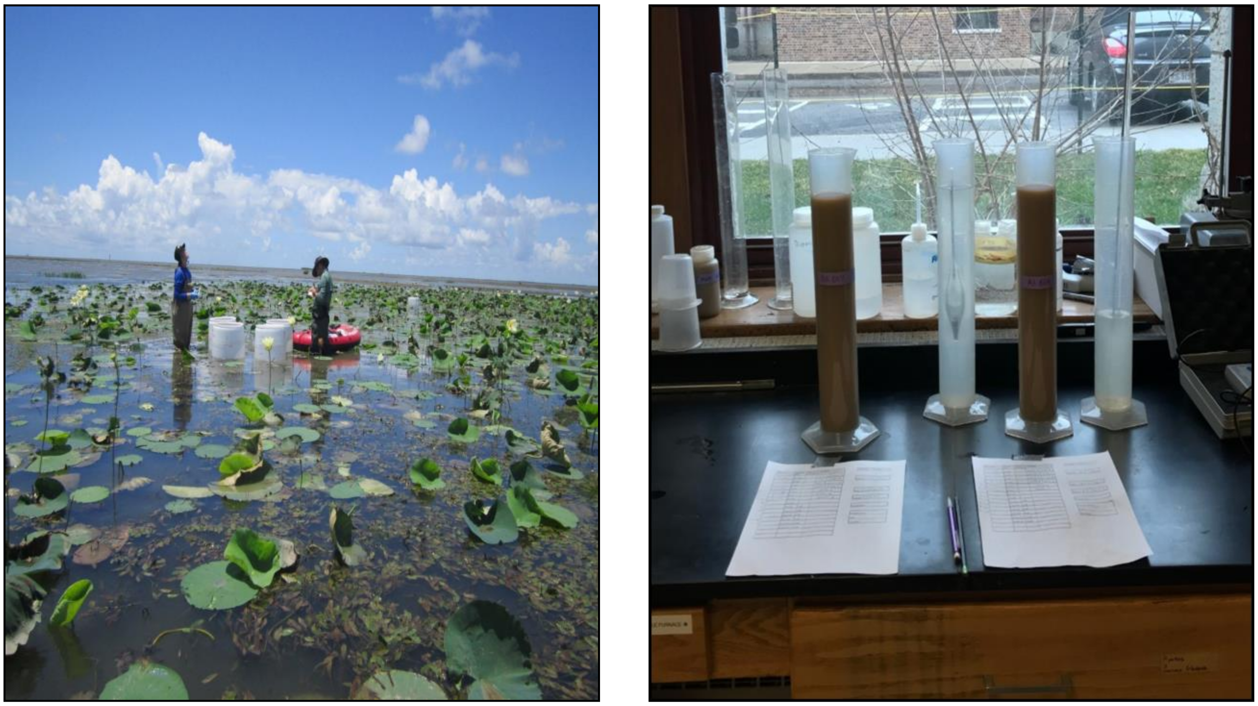

**Figure 2**. Left: Sediment collection was performed near benthic chambers (white barrels in photograph). Right: Sediment analysis was performed at Ohio State a few months after collection.

Five field sites were chosen on Mike Island and visited on June 23, 2018 to June 27, 2018 (one site was visited each day) (Figure 1). At each site, one to six sediment cores were taken. In some cases, a core was taken at each of up to 6 benthic chamber locations where nutrient removal rates were measured as part of a larger study on water quality (Figure 2, left). At some sites, the chambers were located within approximately one meter of one another, as in the example in Figure 2, and the sediment was visually similar, so only one core was collected.

Cores were collected to a depth of 5 cm using a capped 3.6 cm diameter polyvinyl chloride (PVC) corer. The sediment core was extracted, immediately capped on the bottom and placed into plastic Whirly Bags, which were then placed on ice inside of a cooler. Cores were transported to The Ohio State University, where they were refrigerated until analysis.

## Sediment Analyses

Samples were homogenized and split into two fractions. The first split was used for Loss on Ignition (LOI), a proxy for organic matter. In brief, 12-13 grams of wet sediment were placed into a ceramic boat and combusted at 550 degrees Celsius. LOI is calculated by:

LOI = 100% - ((100-Ash weight (g))/Dry weight (g))

according to ASTM D 2974-87. The second split was analyzed for grain size. Specifically, each sediment sample was treated with 30% hydrogen peroxide to remove any organic matter. After the organic matter was removed the sediment was wet sieved to 63 µm according to ASTM C136/C136M-14. The mud (clay+silt) fraction that passed through the sieve (<63 µm) was analyzed with a hydrometer for grain sizes ranging from clay (<2 µm) through silt (2 to 63 µm). The sand fraction (>63 µm) was oven-dried and weighed according to ASTM D 2974-87. More details are available in the Standard Operating Procedure (Appendix A).

## Comparison with Environmental Datasets

Sediment properties were compared with two external datasets. The first data set was the DEM elevation referenced to the NAVD88 datum (Olliver, Edmonds 2017). The horizontal resolution of the DEM is 3 m. The second external dataset was NDVI, a measure of "greenness" or vegetation. The spatial resolution of the NDVI grid is 30 m (Carle 2013). Both datasets were loaded into ArcGIS, and values for elevation and NDVI were extracted at all sites.

Plant communities were also described and photographed at each site for qualitative comparison. Approximate abundances were determined through rough counts using photographs taken at the sites.

## RESULTS

### Physical Sediment Properties

Overall, the areas of study on Mike Island are mud-rich and fairly well-sorted (Figure 3). Note that some sites had more samples than others. For example, only two samples were analyzed from site visited on 6/23/18 (Figure 3). Some of the muddiest samples were sampled on 6/24/18 (red curves in Figure 3) and 6/26/18 (orange curves in Figure 3). Both sites are in the lagoon nor far from a channel and locally have very low flow velocities. The dominant vegetation at both sites is *Nelumbo lutea* (Table 1). Samples from 6/25/18 (blue curves in Figure 3) are some of the sandiest in the study. This site lies in a small depression near a levee along a major distributary channel and has denser, diverse vegetation dominated by *Nelumbo lutea*, *Saggittaria platyphylla* and *Potamogeton pusillus*. The site likely sees flooding under high flow conditions or onshore winds.

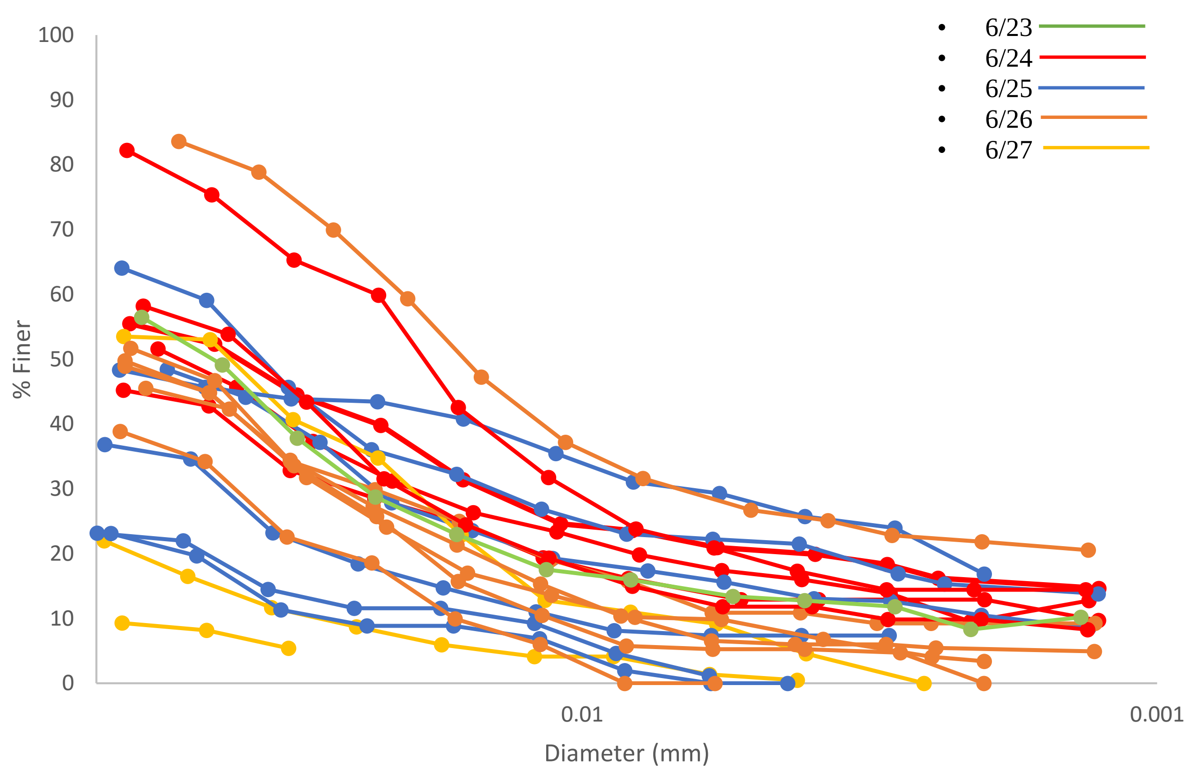


**Figure 3**. Grain size curves for all samples. Color indicates the site and corresponds with color scheme in Figure 1.

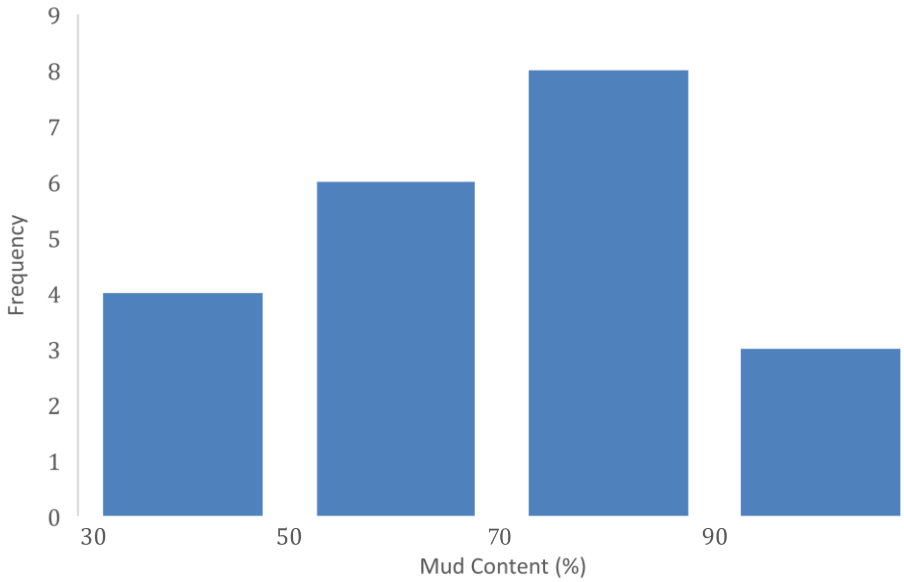


**Figure 4**. Histogram of mud content.

The average mud fraction for all samples (n=24) from the sites is 60.34% with a minimum of 30.91% and a maximum of 97.73% (Figures 3 and 4). Most samples are mud-dominated. The mud fraction is nearly normally distributed (Figure 4).

LOI, a proxy for organic matter content, averages 1.95% and ranges from 0.45% to 10.81% (Figure 5). Most of the samples are low in organic matter, with 16 out of 27 containing less than 1%. LOI is not strongly related to the percent mud (Figure 5). The samples with greatest LOI were collected on 6/25/18 (the levee location). The samples from this site had a large variation, with a range from 0.85 to 10.81%, suggesting a high degree of heterogeneity at this site, which has dense vegetation.

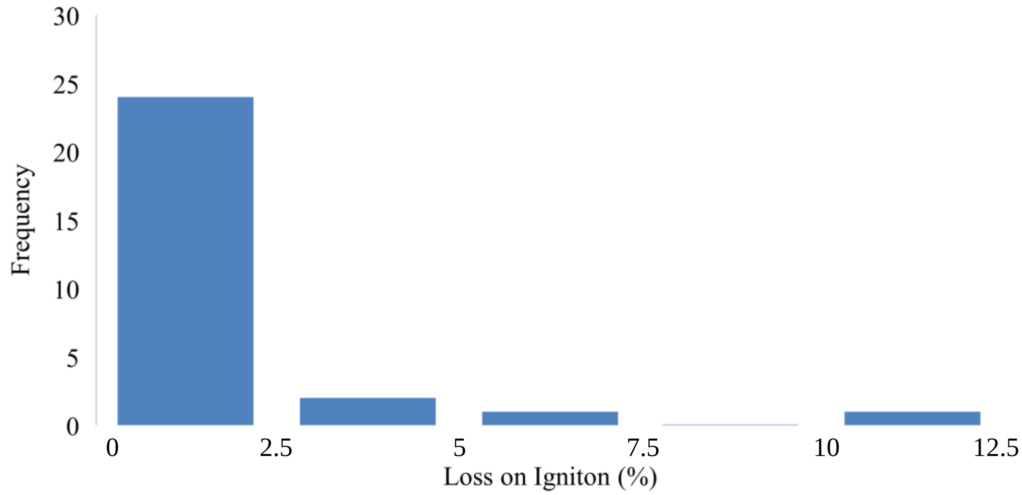


**Figure 5**. Histogram of loss on ignition.

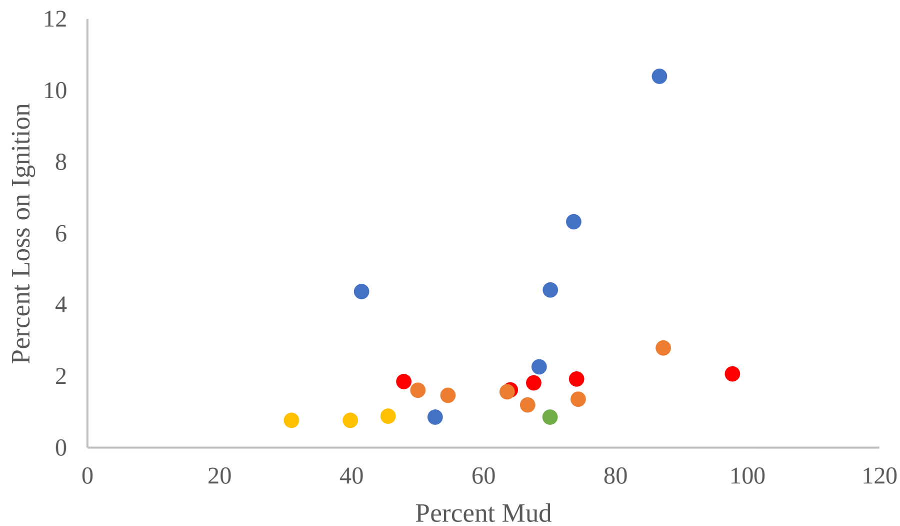


**Figure 6**. Organic matter related to percent mud. Colors correspond with sites on Figure 1.

## Relationship between Sediment Properties and Environmental Variables

Elevation at the 5 sites ranges from -0.14 to 0.25 m, with the site adjacent to the levee having one of the greater elevations. Lower elevations generally correspond to sites near the central portion of the island farther from the island apex. Differences in elevation among sites do not clearly explain the observed differences in grain size (Figure 7) or LOI (Figure 9).

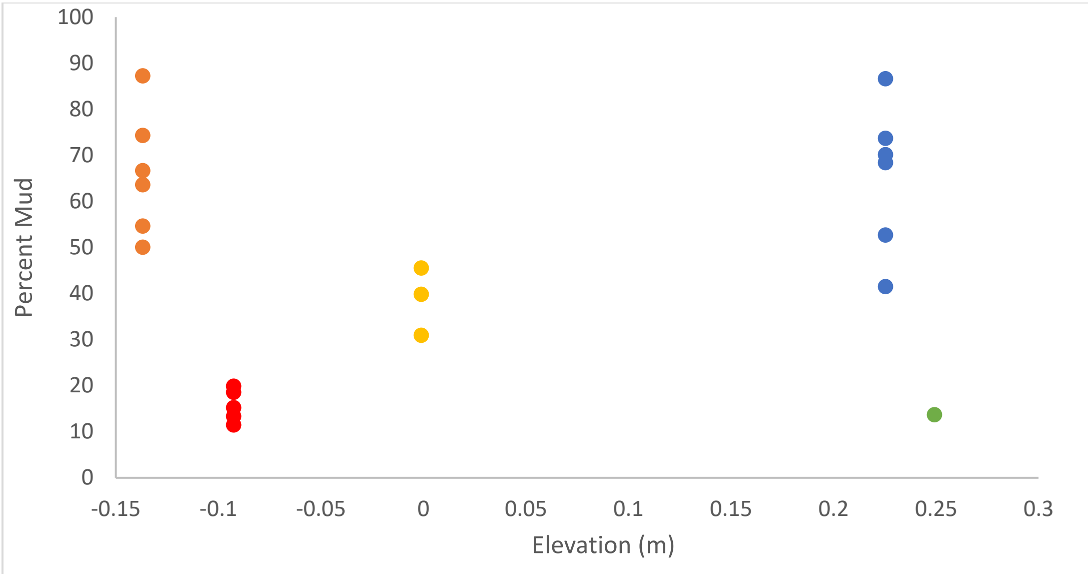


**Figure 7**. No correlation can be seen between elevation and percent mud.

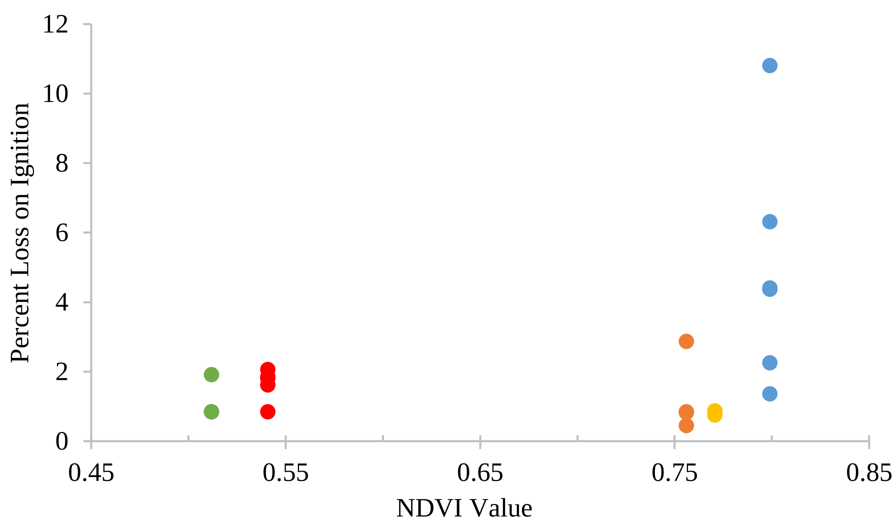


**Figure 8**. NDVI related to organic matter.

NDVI at the 5 sites ranged from 0.51 to 0.79 (Table 1 and Figure 8), with the lowest NDVI value corresponding to the site visited on 6/23/18 in a lagoon. The plant community there was dominantly emergent. The site with the greatest NDVI value was visited on 6/25/18 (the levee site) and had abundant emergent vegetation. Although the relationship between NDVI and LOI is not strong, the site with the greatest NDVI did have the greatest LOI values (Figure 8).

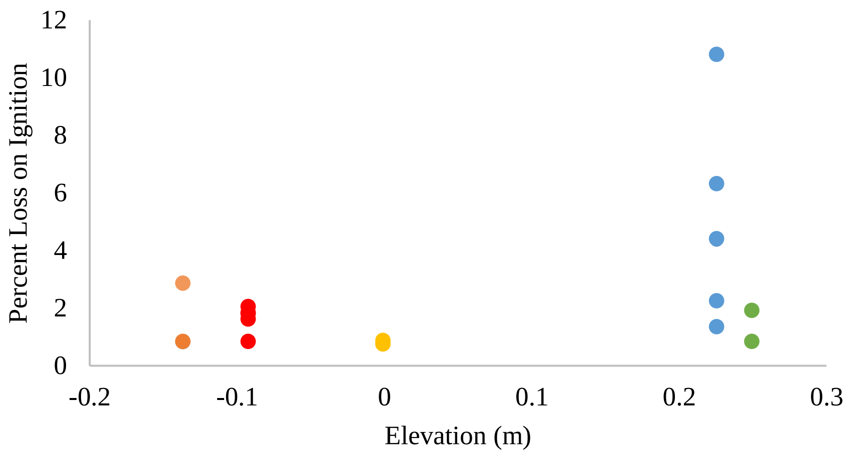


**Figure 9**. Organic matter related to elevation

## Plant Description

There were four main plant species observed at the sites (Table 1). The most abundant species observed was *Nelumbo lutea*. This species was seen at every site with varying abundance. It is a flowering plant that is commonly called the American Lotus and is recognized by large, round leaves and a yellow flower (Figure 10).

Table 1. Description of plant communities at each site: dominant plant species and classification of whether the community was mainly submerged, emergent or floating. The NDVI value for the site is also shown.

| Date | Species | Community Type | NDVI |
|---|---|---|---|
| 23-Jun | Nelumbo lutea | Emergent | .6269 |
| 24-Jun | Nelumbo lutea | Floating | .5118 |
| 25-Jun | Nulembo lutea, Sagittaria platyphylla, Potamogeton pusillus | Floating | .7989 |
| 26-Jun | Nelumbo lutea, Potamogeton nodosus | Submerged | .8165 |
| 27-Jun | Potamogeton nodosus, Sagittaria platyphylla | Submerged | .6558 |

The second most abundant species was the *Potamogeton nodosus*. This species was observed only at two sites, 6/26/18 and 6/27/18. Also known as the Longleaf Pondweed, it is recognized by thin, branching stems that can reach a meter in length. It also has linear leaves that can be both floating and submerged.

The third and fourth species were similarly abundant. The third species, *Potamogeton pusillus*, is also known as Small Pondweed. This species was most abundant at the site sampled on 6/25/18 (Figure 10). This species is in the same family as *Potamogeton nodosus* and has similar characteristics. It also has long thin stems with linear leaves. Pusillus has no floating leaves.

The fourth species, *Sagittaria platyphylla*, is known commonly as Delta Arrowhead. This species was most abundant at the sites visited on 6/25/18 and 6/27/18 but was also seen other places in the delta. This species is recognizable by the arrowhead shape of its leaves, which emerge above the water's surface.

**Figure 10**. Pictures of the vegetation at the sites. Upper left: *Nelumbo lutea*. Upper right: *Potamogeton nodosus.* Bottom left: *Potamogeton pusillus.* Bottom right: *Sagittaria platyphylla*.

## Discussion

Patterns of sedimentation on Mike Island showed the generally expected trends, with some of the coarsest samples found near the levee along the main channel and the finest samples found in the inner lagoon and towards the basin (to the south). These patterns can be explained by high flow events that overtop the levees and deliver sand to areas along the levees. The inner lagoon regions are more isolated from the main flow channels and likely receive coarse material less frequently.

An unexpected result is the large degree of variation in the samples within the same site. For example, the levee site (sampled on 6/25/18) also had mud-rich samples. Furthermore, two of the samples with greater sand content were sampled on 6/27/18 from the lagoon, though other samples at that site were muddy (Figures 1 and 3). These strong variations may be related to variations in bed topography and roughness at the scale of individual plants.

The observed vegetation had large root systems and grew in the water column, which could make the root systems an effective sediment trap over small spatial scales and along the banks of the island. However, no real correlation was seen between our measure of vegetation (NDVI) and percent mud. One experimental weakness is that the scale of NDVI measurements is fairly coarse (30 m) and cannot explain sedimentation processes happening at the scale of individual plants.

I also expected vegetation to play a significant role in contributing to organic matter deposition. Intuitively, denser vegetation would break down to form more organic matter in the sediment. However, sites with greater NDVI values did not have consistently greater organic matter content, or LOI (Figure 8). I expected a much stronger relationship between these two variables. This could be explained by the relatively coarse resolution of NDVI (30 m) and a high degree of heterogeneity in LOI within sites. For example, a sampled region within a site could have low vegetation abundance but a greater NDVI value if the rest of the area were densely vegetated. Timing may also play a role in the lack of strong relationship between NDVI and LOI. The NDVI values are summertime measurements from the approximate time of sampling, while the sediments in grab samples presumably represent material that has been deposited over some longer time interval that may span multiple seasons and years.

These results are important not only for nutrient cycling in modern deltas but also for clarifying aspects of the petroleum system in ancient deltas. After burial, deltas can form valuable petroleum systems because they contain thick deposits of both marine organic matter and sands. Petroleum generation in the source rock occurs when organic matter that is trapped in deposited sediments is heated to ideal temperatures to form hydrocarbons. The amount of organic matter buried in the sediment plays a role in determining the amount of hydrocarbon that will eventually be produced. My samples showed that the amount of organic matter in part of the delta top is highly variable over spatial scales of meters to kilometers. The composition of organic matter was not analyzed in this study, but organic matter composition influences the different types of hydrocarbon produced (Tissot et al. 1974). The amount of sand that is deposited determines the quality of the reservoir rock. Sand-rich facies have high porosity and permeability that create well-connected pore volumes for hydrocarbon storage. This study shows that delta-top wetlands can be highly heterogeneous in terms of sand content both at the map scale and smaller scales within individual sites.

## Conclusions

The objective of this study was to determine patterns of sediment deposition on a delta island. I showed that relatively coarse material was deposited near the levee, but sediment texture varied greatly over length scales of meters within sites too. Percent mud ranged 30-97% across the island. The mud content was not strongly explained by either elevation or NDVI, a measure of greenness. Organic matter content showed a weak relationship with NDVI though. These datasets are being integrated in a larger analysis of nutrient removal within the delta.

## Recommendations for Future Work

Multiple avenues for future research exist that could be explored through a return trip to Wax Lake Delta. An interesting question is how sedimentation changes over time in the delta, and the question could be tested through repeat sampling of the same sites. Deltas grow rapidly over annual to decadal time scales, and changes in the island should alter the influx of sediments. Sampling sediments over these timescales would provide more insight into deltaic deposition cycles. Another option is to go to an older, more established island within the same delta (or a younger island) and repeat the same methods. Furthermore, other deltas could be sampled too. These comparisons could be used to understand trajectories in sedimentation over the lifetime of delta growth. Comparisons could also be made between man-made and natural deltas.

Another avenue is to look at older sedimentation patterns by collecting deeper cores. This could potentially give insight into how ancient deltas are built. Organic matter could be assessed in these cores to understand early diagenetic processes that influence potential for hydrocarbon generation.

Another theme for further investigation is the relationship between vegetation abundance and organic matter in surface sediment, particularly at small spatial scales. This can be investigated with more accurate vegetation counts and many more sediment samples in areas of both high vegetation and no vegetation. Two sites could be studied at high spatial resolution near the head of the island (northern areas with denser vegetation) and distal inner lagoon (southern areas with less vegetation).

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## APPENDIX

### Standard Operating Procedure for Loss on Ignition

- Weigh boat on its own and record
- Fill the boat with wet sediment, weigh and record
- Place boat in oven at 105 °C for at least 12 hours
- After the 12 hours remove the boat from the oven and immediately weigh it, record it, place the boat back in the oven for an hour and record the weight after weighing it a second time. If the weight change is negligible place in furnace, if not place back in 105 °C oven. Make sure the process is done quickly to prevent the addition of water back into the sample.
- Heat the furnace to 550 °C and combust for 4 hours
- After the four hours turn off the oven without opening the door and let sit overnight
- Weigh quickly after removal from the oven to not allow re-entry of water

### Standard Operating Procedure for Hydrometer Analysis

- Place sample into a beaker and treat with 30% hydrogen peroxide to remove all organic matter. Addition ends when the sample ceases to bubble. This process usually takes a couple hundred milliliters of $H_2O_2$ and 1-3 weeks depending on sample size and organic content.
- Empty beaker onto a 63 µm sieve and wet sieve to completion. Transfer the sediment that does not pass through the sieve to a beaker and dry in an oven. The weight represents the sand weight
- The portion of the sediment that passes through the sieve is considered mud(silt + clay). Add this sediment to a one-liter graduated cylinder. Add dispersing agent, sodium hexametaphosphate. Fill graduated cylinder to 1000 mL with de-ionized water.
- Stir the graduated cylinder with a stirring rod for 30 seconds to a minute until the sample is homogenized. Place the hydrometer inside the cylinder. Measure every thirty seconds for the first two minutes. After the first two minutes a measurement is taken in double the time between the last two time steps (for example, 4 minutes then 8 minutes then 16 minutes). Record each measurement once the hydrometer is stable inside the cylinder.
- Make sure not to spill any of the mixture while using the stirring rod and do not move the cylinders. Monitor temperature inside the cylinder and record this as well.
- Enter data into a premade excel sheet that calculates a percent finer than.